Production system design in a global manufacturing context: A case study of a global contract manufacturer

Farhad Norouzilame (farhad.norouzilame@mdh.se)
Department of Product Realization, Mälardalen University, Sweden
LEAX Group Sweden

Jessica Bruch
Department of Product Realization, Mälardalen University, Sweden

Anna Granlund
Department of Product Realization, Mälardalen University, Sweden

Abstract
The aim of this paper is to study the process of production system design in order to identify when and how network capabilities could and should be considered during this process. A case study, investigating the production system design process of a global contract manufacturer has been conducted.

Keywords: Production System Design, Global Manufacturing, Contract Manufacturer

Introduction

As globalization sweeps around manufacturing world, most companies have to build and/or manage an international network of operations either through Mergers and Acquisitions (M&A) activities or via their actual organic growth (De Meyer and Vereecke, 2000). On global scale, an increase of manufacturing activities is reported (Wiktorsson, 2014) that implies expansion of production networks worldwide. This has accordingly changed the role of manufacturing companies from supplying domestic markets with products, via supplying international markets through export, to supplying international markets through local manufacturing (Cheng et al., 2015). Meanwhile, the networked structure of global production companies, aside from capturing new markets, could result in new capabilities acting thus as "*a formidable source of competitive advantage"* as put by Ferdows (2014, p. 1).

The considerable research potential within the global manufacturing networks was identified by some scholars such as Shi and Gregory (1998), Vereecke and Van Dierdonck (1998) and still keeps viable (see e.g. Cheng et al., 2014). Global production networks are complex constructs perceived as new manufacturing systems in terms of mission, structure, infrastructure, capability, and design process (Shi and Gregory, 1998). The research on global manufacturing is vast and dense and different researchers have targeted different sub-areas in

certain levels. *Strategy*, *configuration* and *coordination* have been identified as three main themes in this area (Mundt, 2012). The strategy aspect considers mainly the manufacturing strategy defined as a sequence of decisions that will enable a business unit to achieve its desired competitive advantage (Wheelwright, 1984). Configuration concerns fours subjects: the network structure with its geographic distribution of capacity between the sites within the network; the specialization of the network and sites; the distribution of resources in terms of technology and investment; and the design of the internal supply chain structure (Friedli et al., 2014). The coordination aspect deals with the organization and steering of interplay between the network sites and focuses on questions around the level of autonomy for each site and the exchange of knowledge and information (Mundt, 2012). The latest has been addressed years ago when Flaherty (1986) argued that the coordination of international operations in a network can improve cost and delivery performance and enhance the learning from the experiences of units in the network.

A gap has been identified between the policy-level and operation level which necessitates more research on the design and management of global operation (Ferdows, 2014). In this regard, many researchers have tried to descend from the highest corporate strategic goals to the characteristics of the network and consequently the plants of the network. Years after the introduction of *focused factory* (Skinner, 1974), six different strategic roles for the plants of multinational manufacturers were determined (Ferdows, 1997). Based on this model, Feldmann et al. (2013) took further steps to realize the specifications of the plants and identified three types of plants within a global production network. Besides, Thomas et al. (2013) also investigate how to link the plant capabilities and the network's strategic targets.

Despite the mentioned research, there is no "upward" approach that aims at reaching the network strategic goals via the design of production systems i.e. to establish (implant) the right pre-requirements in the design of production systems that yields to the desired network capabilities. It should be mentioned that 'production system' here refers to the arrangement of main production resources which is different than the company-specific production system (XPS) tailored to the specific characteristics of the company inspired by Toyota Production System (Netland, 2014).

Therefore, in the light of manufacturing globalization, there is a need for a global perspective on design of production systems in order to achieve capabilities in "network" level already from the "plant" level. This paper particularly aims to investigate the potential of attaining desired network capabilities through a case study.

Literature Review

In order to understand and study the process of production system design within global manufacturing networks, definitions and specifics of the comprising terms needs to be addressed. As for design, it is described as devising courses of action aimed at changing existing situations into preferred ones (Simon, 1996). Design thinking has become an integral part of the design and engineering fields as well as business (Razzouk and Shute, 2012). In the realm of manufacturing, parallel to the product design or product development process which has been intensely researched (Krishnan and Ulrich, 2001), is the design of production systems that are intended to produce the designed products. Production system has been defined as "the arrangement and operation of machines, tools, material, people and information to produce a value-added physical, informational or service product" (Cochran et al., 2002) with the main building blocks of: *human*, *technology*, *information*, and *organization* which are in close interaction (Jacobsen et al., 2002). As it is implied from this definition, production system domain can vary from a small part of a plant to the whole

network; however, we prefer to keep the boundaries within a production plant (factory level). Likewise, the network level is seen as the highest structuring level which can be interpreted as production units linked by material and information flows (Wiendahl et al., 2007). The current research focuses on *intra-firm manufacturing networks* which include multi sites within a single organization (Rudberg and Olhager, 2003).

The process of production system design is a multidisciplinary process (Bruch, 2012) which supports manufacturing companies in their attempt to achieve faster time to market, smoother production ramp-up, enhanced customer acceptance of new products, and/or a stronger proprietary position (Hayes, 2006).

Designing production systems which are part of global production networks, adds additional dimensions both from internal (decision within the production system) and external (requirements placed by the global environment) aspects (Norouzilame et al., 2014). In other words, besides ordinary features of a production system on plant (factory) level such as quality, cost effectiveness, and delivery, there are a few capabilities that come out of a well-configured and well-coordinated production network. While some researchers have alluded to such latent potential of a network e.g. Ferdows (1989) and Yip et al. (1992), they have been put into four main categories (Shi and Gregory, 1998) as illustrated in Figure-1.

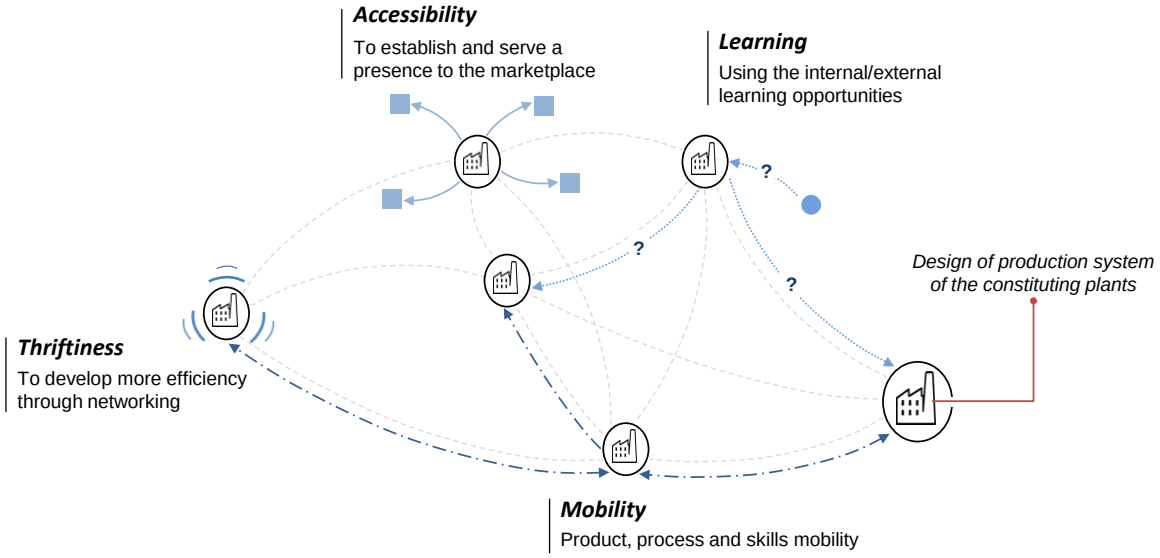

Figure 1 - Network capabilities of production networks (adopted from Shi and Gregory (1998))

Accordingly, the design of production system within global manufacturing context could be seen as a set of decisions which lead to the most optimum combination of the production system building blocks within a global production network providing at the same time the best trade-off between the plant and network priorities.

In the context of global contract manufacturing, production system design becomes even more significant. As contract manufacturers are supposed to provide the customers with more scale flexibility (Schilling and Steensma, 2001), they have to recurrently provide quick solutions to respond to their customer. Additionally, those solutions need to be more cost-effective compared to the competitors' solution or in-house manufacturing. Consequently, contract manufacturers need to have a robust production system design which ensures a quick, effective, and efficient response to the customer which shows the importance of their production systems. Due to the nature of business that contract manufacturers are doing, *manufacturing* is a key source of competitive advantage for such companies which is why they are more likely to build "rooted" production networks (Ferdows, 2008).

Research Methodology

Case study

In order to identify when and how network capabilities could and should be considered, a single case study (Yin, 2013) was conducted including three data collection channels: interviews, documents, and direct observations. The case company was a global contract manufacturer within automotive and telecommunication sector headquartered in Sweden.

In total, ten semi-structured interviews with respondents from different levels of the organization were performed (see Table- 1). The respondents were selected based on their involvement in the production system design process and each interview was adjusted to the respondents' background and role. All interviews were transcribed and sent back to the respondents for data cleaning (Saunders et al., 2011).

Table 1 - Details regarding the performed interviews

Respondents' position	Duration	Content
Chief Operation Officer	120	The production system design process, project model, network capabilities, workflow within a design project
Plant manager	90, 60	
Global project manager	90	
Production and maintenance manager	90	
Quality coordinator and project leader	90	
Global marketing and sales manager	90	

The documents included the project model for production system design in the company and its related education material and strategy documents. The lead author was actively involved in a project at the case company with the aim of developing the company's management system containing six different modules of which one module focused on the project model. In addition, the research benefited from the informal discussions during his presence of the lead author as industrial PhD student in the company for more than two years.

The main unit of analysis was the production system design process of the company with a focus on network capabilities. Data were analyzed based on the suggested guidelines by Merriam (2014) due to the qualitative nature of the data. Primarily, data were coded before putting into different categories. Later on, by sorting the categories, conclusions were drawn after making sense of the analyzed data with linkage to the theoretical knowledge.

Case company selection motivation

The case company was a global contract manufacturer with eleven plants in six different countries. Due to its market, the company continuously encountered diverse orders which entail practicing the production system design in an iterative manner. Thus *production* had a great strategic weight being the company's product offered to their customers as mentioned in the core values of the company: "*our product is our production facilities*". The contracted products included a wide range of mechanical, electromechanical and telecommunication solutions with varying yearly volumes. During the past seven years, the company experienced a considerable growth with seven new production plants; two in Sweden and one in each of the following countries: Germany, Brazil, Latvia, Hungary and China that has brought up new challenges along with the opportunities of the network structure. All in all, the conditions provided a suitable setting to perform the current study in the selected company.

Empirical findings

Production system design process at the case company

Within the case company, the production system was designed through certain stages of a process called 'project model'. The project model was actually the underlying roadmap of typical projects within the company where a production system was designed, implemented and operated based on a specific demand from the customer. It includes all necessary actions and interactions from/among different involving departments and stakeholders demonstrated respectively in two parts in Figure 2 and Figure 3. The project model is elaborated further in a document including all the tasks, responsible people, and reference to a few key documents such as Request for Quotation (RFQ), Production Part Approval Process (PPAP), etc.

The process is comprised of two main parts (separated by contract handover) and five different phases. The first part of the process starts with a quotation request from the customer and ends with a production order (contract) in case the customer is satisfied with the quotation. The second part provides a detailed design of the production solution for the order, implement the design, and run it at full production rate.

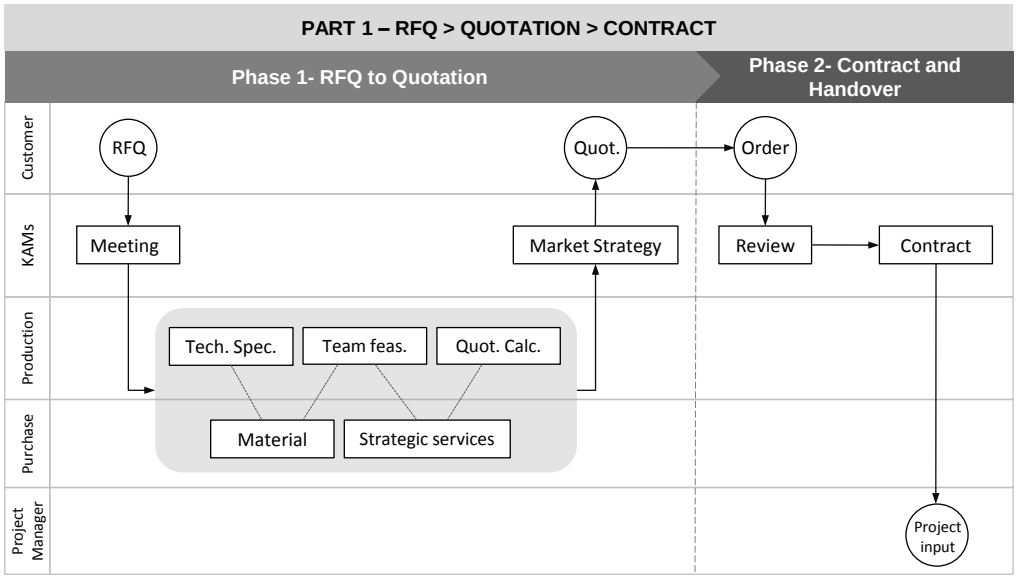

Figure 2 - The project model in the case company (Part 1)

Following a signal from the market which entails a quick analysis over the feasibility of the order, the available competence within the network is assessed. In the very beginning, the irrelevant quotations are excluded. For the interesting quotations, a meeting is held where three main documents, material price and strategic services are discussed among responsible persons from market and sales, production, logistics and purchasing departments. Already in this phase, a rough sketch is prepared which depicts a preliminary design of the production system. The main purpose here is to make sure that the solution will be both feasible and profitable. The results of the RFQ meeting are sent back to the key account managers including three main documents for further compilation and applying market strategy. Then the quotation is submitted to the customer. In case the customer approves the quotation and is willing to proceed with the project, a contract is signed. This happens sometimes after a few interactions between the customer and the marketing department.

The next part of the project model encompasses three phases: detailed design, implementation and handover of the production system to the operation (see Figure-3). In the design stage, which mainly involves responsible people from production and operation as

well as the project manager, the project organization is established and the project is registered in the system. Project specifications are saved on a document including the scope of the project and the project costs. After those steps, the production layout is designed in details. Based on this design, a cost follow-up is prepared upon pre-calculation to spot any deviation. The pre-calculation is taken from an "estimated" flow which specifies the machines and their order.

In the next stage, the design is implemented and a few test orders are produced for the final verifications before reaching the full production rate. When the PPAP is signed by the customer, it is the time for the next stage where production is started and there is a need for auditing that everything is in place. At this point post-calculations are done using the Enterprise Resource Planning (ERP) system output in order to verify if the requirements are met. Then the production system is handed over to the operation and maintenance department.

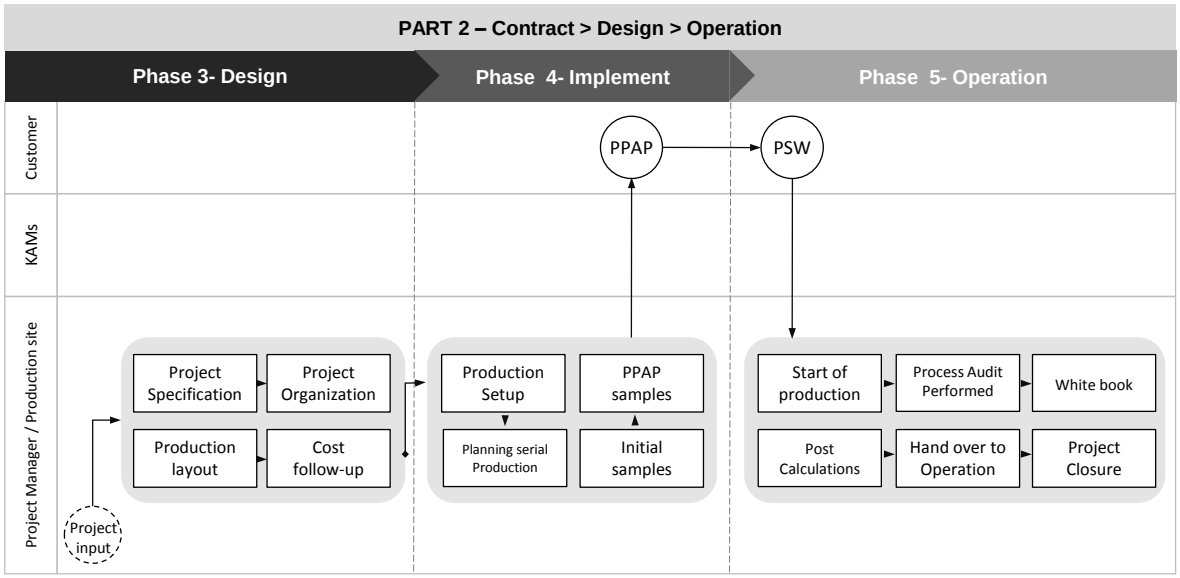

Figure 3 - The project model in the case company (Part 2)

Toward achieving network capabilities through production system design

The network capabilities are not explicitly, if at all, considered during the production system design process of the case company. In fact, apart from the first part of the process where available competence within the network is explored, there is no trace of a conscious solid method to achieve network capabilities within the process. That being said, it became evident that the company had an ambition of exploiting its network structure. So, there existed already awareness about the potential of the network structure. However it was not well specified "when" and "how" in the process this must be considered (implanted) and consequently get operationalized (harvested). A few respondents referred to "white books" as a potential tool that could be utilized in order to be able to trace past projects and learn from them. The white book is a report document prepared by project manager which keeps a diary of the performed project. Nevertheless, the company does not have a well defined strategy for the use of such document; instead, they are used sporadically.

Moreover, regarding the project model, it was understood that although the project model demonstrates a linear sequential process theoretically, in practice the project progresses in different phases at the same time most often. This raises the question of "is the way of working not right or the model is not providing a suitable presentation of the working way?" Although, the detailed design of production system occurs in the third phase, some

issues are already discussed in the first phase. Therefore, it is important to consider the whole flow when it comes to production system design.

Analysis

By studying the process of production system design within the case company, a few potential points were identified in the production system design process of the case company (see Figure 4) which is described in details in the following. The empirical data illustrates that the case company requires a global perspective on the production system design despite the existing ambition to make a better use of their global production network. As mentioned before, the goal was to seek network capabilities via the design of production system within the case company. From literature synthesis, four key network capabilities i.e. learning, accessibility, thriftiness, and mobility where chosen as those represent a concrete rather than abstract model for the network capabilities.

Learning

This is one of the most fundamental abilities which a network of plants can gain by using the knowledge via internal learning mechanisms (Colotla et al., 2003). Although the learning ability refers to a wide scope, here the focus is on potentials through different points of the production system design process.

Already in the first stages, a learning potential is identified. In average, about 25% of all incoming quotations lead to a contract which means that the company does not get to produce approximately 75% of the quotations. This can be due to different reasons such as the company's strategy, competitors, etc. Whatever it might be, there are some potential in understanding the reasons behind not succeeding or accepting those quotation. Today this knowledge stays within a group of key account managers mostly sitting in the headquarters. Besides being an invaluable piece of knowledge for other plants of the network regarding the available competence throughout the whole network, this can provide insights regarding the strategic competence development of the company. This intensifies the importance of *networking* and open constant discussion among the key people within the network as explained by a global marketing and sales manager *"...it can be a matter of five minutes telephone call between two persons in the network to abandon a quotation or turning it to a prosperous contract*" and *"...We can already in the concept study phase go deeper in some key issues and assess the risk of not having a certain competence and decide if we want to invest in such competence and think about what it means for us..."* as the global production manager explained.

The result of the case study also shows that although the production system is designed through different stages, the most crucial phase is the third phase where the production system is designed in fine details in regard to different factors plus the prospective operation. Here again it was revealed that much of this part of the process happens in the mind of the experienced people and lies within personal competency. This hinders knowledge transfer regarding the core activity of the company which signals a high risk of competence loss in case if some resources leave the company. Therefore a learning procedure must be devised in order to transfer the knowledge regarding the detailed design of production system considering the role of the plants.

Another potential point regarding learning in the process which might be case-specific is in the implementation phase. As explained in the empirical findings, a few samples which are critical and are the base for the PPAP to become approved are sent to the customer. Aside from the technical details of these documents, the company could decrease the lead-time of

the projects by producing the parts before approval on its own risk based on former similar project results. Therefore, the information on this stage of the project could be of great significance in the similar prospective projects.

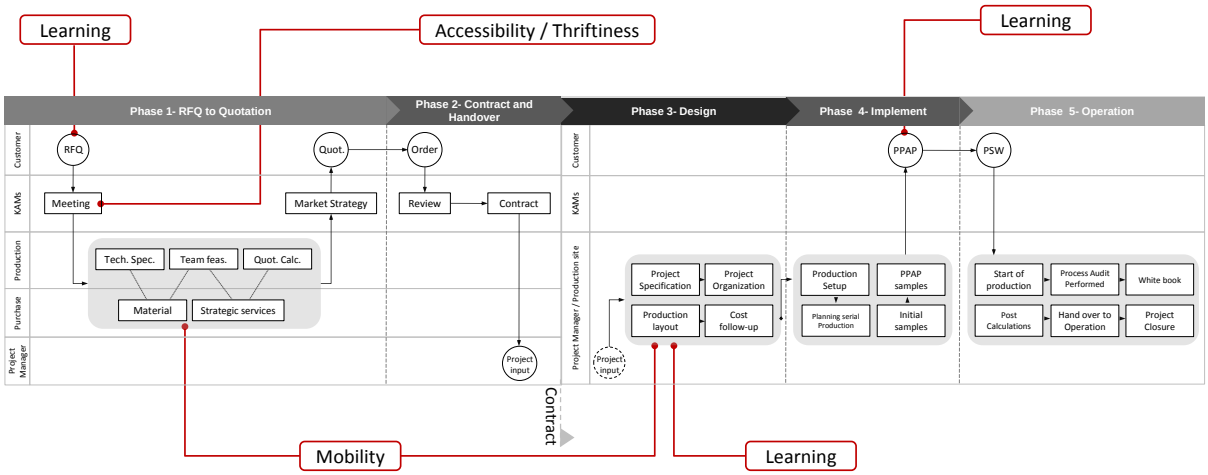

Figure 4 - possibilities of achieving network capabilities when designing the production system

Accessibility and Thriftiness (Economy of scale and scope)

During the initial stage and right after the quotation signal is received from a potential customer, accessibility and thriftiness of the network could be considered. Regarding accessibility, proximity to certain markets, and access to production factors could be discussed. This consequently could help the company to provide thrifty solutions through the existing economy of scale and scope by using the available resources within its network and obtain higher return of investments. The company had a strategy regarding the production machineries which demanded using existing available equipments within the network as much as possible which is in line with the importance of thriftiness or being "economically smart".

Mobility

In some cases, to satisfy the customer demand, there is a need to send resources between certain plants. This could be either managerial or technical skills or the machinery and equipments available in certain plants. Although the company has already a concept for *how* to perform mobility projects, it is still a bit challenging for the company to identify *when* mobility is required. In this case, the question of mobility could be raised in the initial meeting in the first phase (see figure 4) in order to make it clear if there is a need for mobility in a project and what the sender/receiver plants are. Later in the design stage, after the production system is getting ready to be implemented, it is the time to conduct the mobility project which should have already been defined earlier in the first stage.

To sum up, the overall results imply that reaching the network capabilities via the design of production systems is possible to certain extents through a bottom up approach. However, to fully leverage the network structure of a company, there must be a well established strategy that defines the network priorities sent down to the each production units. Those capabilities must then be built in the design of the plants to satisfy the defined strategic priorities upwards. Preferably, this process has to act in a cyclical way to make certain that the desired network capabilities are obtained.

Conclusion

The results of this study augment to other research performed regarding exploiting the network structure of globally dispersed plants. The findings provide important insights in order to fully derive benefits from global production network through the design of its constituting production systems. Production system design within global production networks becomes inherently strategic and sensitive task with long-lasting effects on global firms' fate.

In order to realize the network capabilities and particularly learning ability within the network, communication among the right parties in the whole organization of global manufacturing companies is decisive. This amplifies the critical role of *information* to carry out production system design projects in an effective and efficient manner (Bruch, 2012). Similarly is the significance of *knowledge flow* in Multinational Companies (Michailova and Mustaffa, 2012) which has led to interesting concepts such as *Corporate University* (Konovalenko, 2012).

It is also concluded that the process of production system design deploys different functions and people through complex interrelations and therefore includes critical and valuable information. Some plants with higher strategic roles and specific functions have critical role in realization of network capabilities.

There is still more to explore via research on not only how to capture the desired network priorities out of a global production network but also breaking down network the capabilities into more tangible sub-categories. A few factors could be studied further in this regard some of which are culture, communication and IT.

Finally, more research is required to realize how global manufacturing companies can define, prioritize and achieve strategic network capabilities. This study leans more toward understanding the potential of the process of production system design and aligning it to network capabilities. Further research is needed on wider scope about different methods and tools regarding how to achieve such capabilities in practice and finally achieving generic frameworks in this regard. The current study does not gain its novelty trying to link manufacturing strategy to processes choices, even if it draws attention to that direction. It is rather an endeavor to explore accomplishment of network capabilities via the design of production systems in a global manufacturing context.

References

Bruch, J. 2012. *Management of Design Information in the Production System Design Process.* Doctoral Thesis, Mälardalen University, Sweden.

Cheng, Y., Farooq, S. & Johansen, J. 2014. Global Operations: A Review and Outlook. *International Operations Networks.* Springer.

Cheng, Y., Farooq, S., Johansen, J., Brown, S. & Brown, S. 2015. International manufacturing network: past, present, and future. *International Journal of Operations & Production Management,* 35.

Cochran, D. S., Arinez, J. F., Duda, J. W. & Linck, J. 2002. A decomposition approach for manufacturing system design. *Journal of manufacturing systems,* 20**,** 371-389.

Colotla, I., Shi, Y. & Gregory, M. J. 2003. Operation and performance of international manufacturing networks. *International Journal of Operations & Production Management,* 23**,** 1184-1206.

De Meyer, A. & Vereecke, A. 2000. *Key Success Factors in the Creation of Manufacturing Facilities Abroad*, INSEAD Euro-Asia Centre.

Feldmann, A., Olhager, J., Fleet, D. & Shi, Y. 2013. Linking networks and plant roles: the impact of changing a plant role. *International Journal of Production Research,* 51**,** 5696-5710.

Ferdows, K. 1989. Mapping international factory networks. *Managing international manufacturing***,** 3-21.

Ferdows, K. 1997. Making the most of foreign factories. *Harvard Business* 75**,** 73-91.

Ferdows, K. 2008. Managing evolving global production networks. *I: Strategy Innovation and Change: Challenges for Management, R. Galvan, ed., Oxford: Oxford***,** 149-162.

Ferdows, K. 2014. Relating the Firm's Global Production Network to Its Strategy. *International Operations Networks.* Springer.
Flaherty, M. T. 1986. Coordinating international manufacturing and technology. *Competition in global industries,* 198**,** 83-109.
Friedli, T., Mundt, A. & Thomas, S. 2014. *Strategic Management of Global Manufacturing Networks*, Springer.
Hayes, R. 2006. Operations, Strategy, and Technology: Pursuing the competitive edge. *Strategic Direction,* 22.
Jacobsen, P., Pedersen, L. F., Jensen, P. E. & Witfelt, C. 2002. Philosophy regarding the design of production systems. *Journal of manufacturing systems,* 20**,** 405-415.
Konovalenko, V. 2012. *A" coordination Kaleidoscope": The Role of a" corporate University" as a Coordinator of Knowledge Flows in a Russian Transnational Corporation*, University of Nordland, Bodø Graduate School of Business.
Krishnan, V. & Ulrich, K. T. 2001. Product development decisions: A review of the literature. *Management science,* 47**,** 1-21.
Merriam, S. B. 2014. *Qualitative research: A guide to design and implementation*, John Wiley & Sons.
Michailova, S. & Mustaffa, Z. 2012. Subsidiary knowledge flows in multinational corporations: Research accomplishments, gaps, and opportunities. *Journal of World Business,* 47**,** 383-396.
Mundt, A. 2012. *The Architecture of Manufacturing Networks- Integrating the Coordination Perspective.* Doctor Oeconomiae, University of St.Gallen.
Netland, T. H. 2014. Coordinating Production Improvement in International Production Networks: What's New? *International Operations Networks.* Springer.
Norouzilame, F., Bruch, J. & Bellgran, M. 2014. Production plants within global production networks: Synergies and redundancies. *21st European Operations Management Association.* Italy.
Razzouk, R. & Shute, V. 2012. What is design thinking and why is it important? *Review of Educational Research***,** 0034654312457429.
Rudberg, M. & Olhager, J. 2003. Manufacturing networks and supply chains: an operations strategy perspective. *Omega,* 31**,** 29-39.
Saunders, M., Lewis, P. & Thornhill, A. 2011. *Research methods for business students, 5/e*, Pearson
Schilling, M. A. & Steensma, H. K. 2001. The use of modular organizational forms: an industry-level analysis. *Academy of Management Journal,* 44**,** 1149-1168.
Shi, Y. & Gregory, M. 1998. International manufacturing networks—to develop global competitive capabilities. *Journal of operations management,* 16**,** 195-214.
Simon, H. A. 1996. *The sciences of the artificial*, MIT press.
Skinner, W. 1974. *The focused factory*, Harvard Business Review.
Thomas, S., Scherrer-Rathje, M. & Friedli, T. Plant role portfolios in global manufacturing networks: a conceptual framework. 20th EurOMA Conference, 2013 Dublin. European Operations Management Association, 1-10.
Vereecke, A. & Van Dierdonck, R. Design and management of international plant networks. 29th Annual Meeting of the Decision-Sciences-Institute, 1998. DECISION SCIENCES INSTITUTE, 1319-1321.
Wheelwright, S. C. 1984. Manufacturing strategy: defining the missing link. *Strategic Management Journal,* 5**,** 77-91.
Wiendahl, H.-P., Elmaraghy, H. A., Nyhuis, P., Zäh, M. F., Wiendahl, H.-H., Duffie, N. & Brieke, M. 2007. Changeable manufacturing-classification, design and operation. *CIRP Annals-Manufacturing Technology,* 56**,** 783-809.
Wiktorsson, M. 2014. Consideration of Legacy Structures Enabling a Double Helix Development of Production Systems and Products. *Technology and Manufacturing Process Selection***,** 21-32.
Yin, R. K. 2013. *Case study research: Design and methods*, Sage publications.
Yip, G. S., Loewe, P. M. & Yoshino, M. Y. 1992. How to take your company to the global market. *International Strategic Management: Challenges and Opportunities***,** 99.